N93-32121

JSC FLIGHT EXPERIMENT RECOMMENDATION IN SUPPORT OF SPACE STATION ROBOTIC OPERATIONS

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August 4, 1992

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1 OVERVIEW

1.1 BACKGROUND

The man-tended configuration (MTC) of Space Station Freedom (SSF) provides a unique opportunity to move robotic systems from the laboratory into the mainstream space program. Restricted crew access due to the Shuttle's flight rate, as well as constrained on-orbit stay time, reduces the productivity of a facility dependent on astronauts to perform useful work. A natural tendency toward robotics to perform maintenance and routine tasks will be seen in efforts to increase SSF usefulness. This tendency will provide the foothold for deploying space robots. This paper outlines a flight experiment that will capitalize on the investment in robotic technology made by NASA over the past ten years. The flight experiment described herein provides the technology demonstration necessary for taking advantage of the expected opportunity at MTC.

As a context to this flight experiment, a broader view of the strategy developed at the Johnson Space Center (JSC) is required. In reference to Figure 1, JSC is building toward MTC by developing a ground-based SSF emulation funded jointly by internal funds, NASA/Code R, and NASA/Code M. The purpose of this ground-based Station is to provide a platform whereby technology originally developed at JPL, LaRC, and GSFC can be integrated into a near flight-like condition. For instance, the Automated Robotic Maintenance of Space Station (ARMSS) project integrates flat targets, surface inspection, and other JPL technologies into a Station analogy for evaluation. Also, ARMSS provides the experimental platform for the Capaciflector from GSFC to be evaluated for its usefulness in performing ORU change-out or other tasks where proximity detection is required. The use and enhancement of these ground-based SSF models are planned for use through FY93. The experimental data gathered from tests in these facilities will provide the basis for the technology content of the proposed flight experiment.

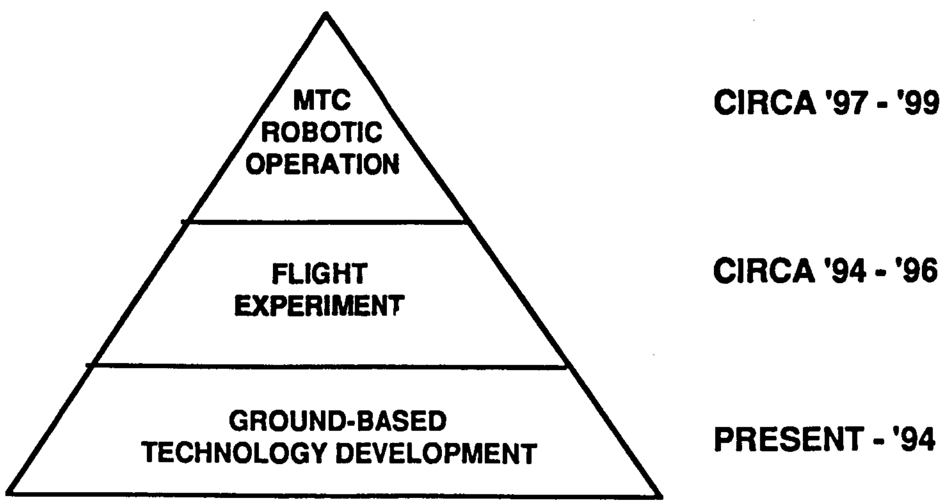

Figure 1 - Technology Progression to MTC

1.2 FLIGHT EXPERIMENT GOALS AND OBJECTIVES

The goal of this proposed flight experiment is to demonstrate the maturity, suitability, usefulness, and availability of robots in performing SSF required tasks. This goal will assist the NASA robotics community in obtaining its broader purpose, to enhance the productivity of Space Station Freedom through the implementation of robotic devices.

To achieve the goals of the flight experiment, several technology objectives must be demonstrated. During the initial man-tended phase of SSF, the ability to perform space operations with robots under remote (ground) control is a necessity. This technology is commonplace in terrestrial applications, but has never been adequately demonstrated in low Earth orbit (LEO). A flight experiment must demonstrate this capability, not in simple robot motions, but rather, in the performance of meaningful SSF derived tasks. Under ground control, the ability to conduct useful space operations needs to be demonstrated in both IVA and EVA environments. This proposal addresses each of these objectives.

1.3 FLIGHT EXPERIMENT DESCRIPTION

The MTC Station can be subdivided into two technology development areas: EVA robotics (EVR) and IVA robotics (IVR). To fully utilize the Station, robotic systems must function in both of these areas under remote control from the ground operations facility. This paper describes an Orbiter flight experiment that addresses these development areas.

Seizing the robotic opportunities of MTC will require SSF robots to be controlled from the ground. This requirement is made difficult by the command and feedback time delays expected in this communication link. Nevertheless, this obstacle must be overcome if robots are to provide the functionality required as full participants in the SSF program. JSC is currently working with the mission controllers to establish a communication path through the nominal mission command links. This path includes the mission control facility, TDRSS, and White Sands. The ground based SSF emulation systems mentioned earlier, namely ARMSS, will be controlled through this communication path. We expect the experiences gained in these ground based experiments to be valuable in addressing the control of robots in low Earth orbit (LEO). Of particular help in solving this problem will be the transfer to JSC of JPL technologies in remote teleoperation and operator coached machine vision. These technologies are planned to be transferred as part of the ARMSS project.

For the proposed flight experiment, JSC proposes the use of its robot ground control system being developed for the ARMSS project. This system is integrated with the mission control network at JSC and can provide the required control capability as well as the proper level of security. Certified crew members will be used to operate the flight experiment from the JSC ground facility. The experiment operations will include various operators performing identical tasks to extract human factors data that is independent of any single crewman. This approach provides a useful baseline of operational data for evaluating experiment performance. LaRC, JPL, and GSFC will be responsible for defining a portion of the experiment, providing a task panel, and training the crew teleoperators in the operation of their respective task panel.

JSC will include the Unversity Space Automation and Robotic Consortium (USARC) in the data analysis process. USARC is a consortium of Texas research universities (Univ. of Texas at Austin, Rice Univ., Texas A&M, and the Univ. of Texas at Arlington) and JSC that are engaged in the development of remote teleoperation technology for use in space. A network has been established that allows an operator at one university to control robots at another. As part of these experiments, UT-Arlington monitors operator inputs and provides human factors analysis. JSC will utilize this capability throughout this experiment to interpret the results from the teleoperation data received during the tests.

Based on JPL remote control technology and requirements from the mission controllers, an advanced ground control station will be designed and constructed at JSC. During the flight experiment, JSC will conduct the mission ground operations through the use of certified crew operators. Each participating Center will be responsible for crew training for their respective segment of the experiment.

1.3.1 EVA ROBOTIC ELEMENT

Currently, JSC and LaRC are involved in the technology capture of the Flight Telerobotic Servicer (FTS) program. The technology capture program provides LaRC with a hydraulic manipulator (that is similar to the flight manipulator), a hand controller, and control software. JSC is managing the continued development of the flight manipulator through final assembly and integration. The goal of this program is to establish a remote communication such that the flight manipulator can be controlled at JSC from LaRC.

The experience gained from this ground experiment with LaRC leads to the recommendation that the FTS be flown in the payload bay of the Orbiter. In this scenario, the FTS is planned to be attached to an MPESS along with a SSF and technology derived task panels developed by the research centers. The ground control and MPESS are critical items in scenario because they both serve to minimize Orbiter integration costs. By performing a SSF task the effectiveness of the technology can be assessed under flight utilization conditions. In constructing this flight element, each Center (JPL, LaRC, and GSFC) would be responsible for a portion of the experiment and the development of their own task panel. These panels would be mounted on the forward end of the MPESS. The Remote Manipulator System would be used to move the task panels to the top of the MPESS, in succession, for manipulation by the FTS.

In addition to the FTS in the payload bay, the flight experiment should include a test of the Autonomous EVA Camera (AERCAM) system. This system provides controllers with a mobile camera that can be optimally placed to support robotic teleoperations. With the myriad of possible external maintenance functions for robots on MTC, this simple "flying camera" provides the support viewing required to perform these tasks under ground control. In addition, surface inspection technology (developed at JPL) can be hosted on this system to examine areas not accessible to baselined robots, such as the solar arrays. Requirements for this system include the ability to be positioned through teleoperation, autonomous station keeping, and autonomous collision avoidance that takes precedence over teleoperator inputs. The AERCAM portion of the flight experiment includes the pre-positioning of SSF surface panels in multiple locations around the payload bay. These panels will depict expected damage resulting from exposure to the orbital environment. The AERCAM will conduct an inspection of these surfaces through intelligent "wandering" to identify areas of damage. The intelligence embedded into this system will make it a safe and useful partner in conducting on-orbit robotic operations. To minimize the Orbiter integration process and reduce launch costs, this device is configured to fit into the Get-Away-Special (GAS) cannister located on the payload bay longeron. In addition, the AERCAM will be padded to protect the Orbiter from inadvertent collisions.

1.3.1.1 PRINCIPAL INVESTIGATOR

The payload bay element development would be led by JSC. Control software to operate the FTS arm will be delivered from LaRC to JSC as part of the FTS Technology Capture program. Each research center (JPL, LaRC, and GSFC) would be responsible for producing their own task panel based on their own technology requirements and JSC supplied SSF requirements, and for training the crew for the operation of their respective portion of the experiment. JSC would also define interface requirements to the research centers for attachment of the task panel to the MPESS.

1.3.2 IVA ROBOTIC ELEMENT

Many of the scientific and maintenance operations planned for SSF are confined to the habitable volumes of the spacecraft. A robot designed to operate in this environment can provide ground controllers with a productive tool for accomplishing these tasks. JSC proposes to conduct a study of candidate tasks to be performed by an IVA robot. After this survey has been completed, the results will be evaluated to determine if the IVA robot should be included in the flight experiment. If included, this robot would be designed to operate in the pressurized cabin of the Station, or in this case, the Orbiter middeck or SpaceHab. A SSF task panel derived from the survey can be fitted into the foot lockers on the forward wall of the middeck or in the SpaceHab module. These tasks should demonstrate the ability of the robot to perform the series of tasks identified in the task survey.

If, after completing the task study, the IVA robot is included in the flight experiment, special consideration must be made for minimizing Orbiter integration costs. Depending on size and configuration, the robot may be attacted to structural interfaces on the floor of the airlock, similar to the Extravehicular Mobility Unit (EMU, space suit). Alternatively, the robot may be attached directly to the middeck seat interfaces on the floor. The integration details would be finalized as part of the development of this robot.

1.3.2.1 PRINCIPAL INVESTIGATOR

Since the IVA robot would be utilized in the operation of the Station, JSC will conduct a study to determine system requirements.

1.4 FLIGHT EXPERIMENT OPTIONS

Although JSC believes that the flight experiment, composed of EVA, IVA, and ground control components, is the right step for the Agency, fiscal constraints may dictate a more conservative approach. With this in mind, the following options are presented in priority order and can be combined in any way consistent with budgetary authority. In all cases, the experiments are proposed to be controlled from the ground, testimony to the importance placed on this technology at JSC.

1.4.1 OPTION 1 - FLIGHT TELEROBOTIC SERVICER

The FTS is selected as the highest priority because of the investment made in its development and the usefulness of its capability. NASA has spent significant resources in the design and development of this manipulator and should follow through with a flight demonstration of its capability. Only through the rigors of the flight experiment will the design decisions made during the development process be validated. This option can include the use of task panels developed at the research centers with each Center providing crew training for their respective equipment. Task panel changeout can be accomplished with the Orbiter's Remote Manipulator System (RMS) demonstrating a cooperative robot task. The proposed cooperative task provides for the FTS to manipulate latches that secure (and release) the task panels after being positioned by the RMS. For example, to remove a task panel, the RMS grapples the panel and waits for the FTS to remove a securing latch before lifting it from the workspace.

1.4.2 OPTION 2 - AERCAM

The AERCAM system is proposed as the next highest priority in this proposal. The needs, identified within the SSF program, for additional camera views to support SSF assembly and long term robotic operations make this project the next highest priority. EVA robotic systems have already enjoyed SSF program support due to success with the Orbiter RMS, the Fisher/Price SSF External Maintenance Report, and international agreements. However, analysis conducted within the program has indicated additional viewing requirements for proposed robotic operations (e.g. assembly, maintenance). The AERCAM system is derived in answer to these needs. The AERCAM can provide bird's eye views of robotic operations, Orbiter approach and berthing, as well as provide inspection capability outside the workspace of existing program robots. Its simplicity and low cost, combined with its ability to enhance existing SSF systems, supports this project as the second highest priority.

For this flight experiment, the AERCAM will be deployed and retrieved using the Orbiter RMS. JSC proposes the use of the Magnetic End Effector (MEE) and Force/Torque Sensor attached to the tip of the RMS to perform these operations. The MEE, developed at JSC, and the Force/Torque Sensor, developed by JPL, are currently set to fly in 1994. Utilizing this system minimizes impacts on the AERCAM design attributed to the grapple and retrieve function.

1.4.3 OPTION 3 - IVA ROBOT

Although the concept of an IVA robot has been discussed in many technical circles, system requirements have not been formalized. However, JSC believes this is an important technology area and a necessity for MTC. A study will be initiated at JSC to better understand the system level requirements for such a device.

1.5 MISSION PROFILE

To conduct this flight experiment, a nominal mission profile for the Shuttle is projected. The MPESS, holding the FTS, would be positioned in the payload bay with the task panels (developed by the participating research centers) on the forward face. The GAS cannister would house the AERCAM system with the IVA robot, if included, attached to a support system in the airlock. The mission profile would not be dedicated to the flight experiment in that other payloads could coexist with the proposed experiment equipment. An Orbiter RMS equipped with the MEE and Force/Torque Sensor, to be used to changeout task panels and stow and deploy the AERCAM, would be required for this flight.

1.6 EXPERIMENT PROFILE

The test of the AERCAM system would occur first in the integrated experiment mission timeline. The AERCAM system would be powered up in the GAS cannister and deployed by the Orbiter RMS utilizing the MEE. While attached to the RMS, a communication and function checkout will be conducted on the AERCAM systems. The AERCAM will be released in a quiescent mode in the payload bay of the Orbiter. In addition to its exterior padding, the energy capacity of the AERCAM will be limited to preclude Orbiter damage if collisions occur. The AERCAM, under ground control, will be flight tested to verify its controllability. During the flight test, the video cameras will be pointed at targets in the Orbiter payload bay and autonomous station keeping tests will be conducted. To further test AERCAM's intelligence, test panels (attached to the payload bay) that depict damage induced by the on-orbit environment will be surveyed and compared against a baseline (no damage) database to test the system's ability to identify damaged SSF areas. At the conclusion of the AERCAM flight test, the system will be returned to a quiescent mode and retrieved, using the MEE, by the Orbiter RMS.

The next experiment phase of the mission will be the teleoperation of the FTS. With a task panel in place, the RMS (with the AERCAM still attached) will position the AERCAM to assist the FTS teleoperation experiments. The FTS experiments on the first task panel will be conducted through ground teleoperation. Following the completion of the task panel experiments, the RMS will release the quiescent AERCAM and changeout the task panel. The RMS will then re-grapple the AERCAM and position it to provide viewing assistance for the FTS experiment. At the completion of the FTS experiment, the RMS stows the AERCAM in the GAS cannister for the return flight.

If included as part of the experiment, the next item in the mission timeline is the IVA robot experiment. For this experiment the crew will configure the robot and task panel for the experiment. Again, through ground teleoperation, the robot will be used to perform tasks on a Station IVA derived task panel. At the conclusion of the experiment, the IVA robot and other test equipment will be stowed on the middeck (or SpaceHab module) for the return flight.

1.7 DATA COLLECTED

The primary purpose of the experiment will be to verify the capabilities of ground teleoperation of space-based robots. Data will be in the form of system operation telemetry as well as video of the experiment. Data will also be taken from the ground control center for analysis of workload, deficiencies, etc. One of the key data sets taken from this flight experiment will be the information regarding task performance by a statistically significant set of crewmembers. This data will depict experiment performance independent of the skill level of a particular crewman. This type of data is necessary before meaningful conclusions can be drawn from the experiment. As mentioned earlier, JSC proposes to utilize the human factors team at the Univ. of Texas-Arlington to assist in the analysis of the experiment data.

1.8 LAUNCH MECHANISM

In preparing for MTC, the Orbiter provides an excellent platform for the development of operational flight systems. Every functional aspect of the MTC Station can be represented in the Orbiter configuration. External robotic activities planned for the Station's transverse boom can be hosted in the Orbiter's payload bay. Robotic systems developed for operations inside the habitable volume of SSF are well suited for the Orbiter middeck. The Orbiter's communication channels through the TDRSS is similar to that expected on SSF, thereby providing the framework for testing ground control. Also, a flight experiment on the Orbiter, where manned spaceflight safety issues must be faced, demonstrates the readiness of robotic technology to be flown on SSF. These factors are the primary reasons for JSC to recommend an Orbiter-based flight experiment.

On this flight, the Orbiter will be required to include the RMS to conduct the EVR aspects of the flight experiment. There are several benefits for utilizing the Space Shuttle for this experiment. First, a complement of Flight Support Equipment (FSE) is available for use. This enables the payloads to be easily integrated in the Orbiter when these standardized systems are used, minimizing integration costs. The use of existing FSE also means that experiment resources ($) can be applied directly to the experiment hardware and not into the development of customized FSE. Also, the crew is available to assist in the experiments. This can be helpful in troubleshooting as well as taking data from the experiment.

1.9 PAYLOAD CHARACTERISTICS

The payload bay experiment equipment will utilize existing Orbiter FSE including a MPESS and a GAS cannister. An IVA robot could be structurally attached to the airlock EMU interface. The FTS experiment, including MPESS and task panels, will weigh approximately

4500 lbs. The AERCAM system will weigh approximately 200 lbs. and be about 28 inches tall with a cylindrical diameter of 19 inches. The IVA robot will also be in the 200 lbs class and located in the Orbiter middeck.

2 TECHNOLOGY DEMONSTRATED

Flight experiments, based on expected program requirements, provide the benefit of focussing individually developed technologies into a single application that is greater than the sum of its parts. However, perhaps the greatest benefit from a robotic flight experiment is the demonstrated solution to otherwise unsolvable programmatic problems. By demonstrating the usefulness, and readiness, of new technology through flight experiments, program managers can include these systems at less program cost and risk.

To control the Orbiter-based robots, JSC proposes the use of advanced teleoperated ground control. The primary technologies included in the ground control of the flight experiment deal with the remote control of robots in a time delay environment through telepresence. Ground based experiments planned at JSC will help define the limitations of remote teleoperation and provide better understanding of the levels of shared control. The shared control technology will be the basis of the ground control telepresence workstation. An important aspect of this ground control system is the integration of this control system with Mission Control at JSC. Mission Control systems utilized to perform this flight experiment provide a precedent for controlling SSF robots at MTC. This section outlines the various technologies and resulting program capabilities for each of the elements of the flight experiment described in this paper.

2.1 EVA ROBOTICS

The FTS arm proposed for the payload bay robotics experiment represents a technology unto itself. It represents a significant investment in technology to provide a flight qualifiable arm for use in space applications. After final assembly and integration of the arm, JSC plans to continue the flight qualification process through onsite environmental testing. In the proposed flight experiment, task panels will be developed by JPL and LaRC to explore such technologies as force reflection in a delayed environment, shared control between the operator and the robot, and control system performance and stabilty. These technologies will be applied to the SSF based task panel to perform surface inspection, ORU changeout (including the GSFC developed Capaciflector), and SSF access door manipulation. The manipulator itself will also be an object for experimental inquiry. The arm, unable to be exercised in a gravity environment, will be investigated for arm kinematic and dynamic characteristics as well as non-linear behaviors in the gear train.

The AERCAM system provides a simple hardware platform for experimentation with sophisticated software algorithms. The hardware is based on a cold gas propulsion system developed at JSC for the Simplified Aid For EVA Rescue (SAFER) project. Added to this existing propulsion system is a complement of stereo and monocular cameras. This component of the flight experiment is required to be teleoperated to a desired position relative to the Orbiter. The teleoperation of this mobile robot will occur under a supervisory software level that avoids collisions with the Orbiter. Once the robotic camera is in the desired position, an autonomous station keeping mode will be engaged. The AERCAM will be required to maintain its position relative to the Orbiter by compensating for orbital mechanics disturbances. During this phase of the experiment, the station keeping technology must be demonstrated with the Orbiter in Local Vertical, Local Horizontal (LVLH) flight mode, similar to the nominal SSF flight orientation.

2.2 IVA ROBOTICS

The development of an IVA robot could include several advanced technologies. The robot must be capable of teleoperation under autonomous collision avoidance supervision. Also, advanced sensor technologies, used for telepresence feedback and adapted for time delays, are also required in this system to provide input to the control station at JSC.

3 USER INTEREST

The proposed flight experiment produces results meaningful to both near and long term space goals. The robotics research community within NASA can integrate selected technologies into the experiment and verify their usefulness in the space environment. This helps to verify levels of maturity and identify future funding needs and technology priorities. However, perhaps most important is that the technology demonstrated in this flight experiment can enable activities in future lunar and Mars exploration scenarios. The ability to remotely control robots on the moon to perform assembly and maintenance tasks can leverage the available crew time to enhance productivity. In fact, this technology will be an integral component in the success of these future programs.

3.1 COFUNDING/COSPONSORS

Potential sponsors of this flight experiment exist in NASA/Code R as well as other NASA departments. For example, NASA/Code X may have an interest in the enabling robotics technology demonstrated in this experiment. The Space Exploration Initiative may wish to encourage space robotic innovation for use in their proposed lunar and planetary scenarios.

4 PROGRAMMATIC IMPACT

The flight experiment described herein seeks to minimize the STS programmatic impacts. The development strategy with respect to the flight experiment is to design the proposed robots to existing Orbiter interfaces. This enables the systems to be integrated into the launch manifest more easily. Existing FSE is proposed for each flight element as a way of reducing integration costs and focussing resources into the experiment hardware.

5 TELE-ROBOTIC PROGRAM DEVELOPED TECHNOLOGY

The proposed flight experiment is an extension of the current working plan between JSC and other NASA Centers (JPL, LaRC, and GSFC). JSC is developing a high fidelity representation of the SSF system in the laboratory as a means for integrating and evaluating new technologies. The proposed flight experiment would apply those technologies from the research centers that have been integrated into the JSC "ground-based" SSF and integrate them into the flight experiment. This method applies the maximum set of developed technologies that have demonstrated the necessary maturity for flight.

This flight experiment seeks to include relevant technologies developed at the research centers as integral components of the experiment hardware. Some of these technologies have been identified through the technology transfer process currently being accomplished in the ARMSS project. This non-inclusive list of technologies are:

Capaciflector, GSFC

Operator Coached Machine Vision, JPL

Flat Targets, JPL

Remote Site Shared Control, JPL

Surface Inspection, JPL

User Macro Interface, JPL

Magnetic End Effector, JSC

6 POTENTIAL OPERATION IMPACT

The purpose of the proposed flight experiment is to develop technology which can first be used on the Space Station. Its impact would not be on the hardware design of the Station, since the experiment would occur too late in the design cycle. Instead, this experiment would have a profound effect on the operation of the Station. No longer would operation of the MTC Station be confined to the limited periods of crew visits. The flight experiment would provide the Station program with options for using robotic systems to enhance Station operability. The projected experiment time frame aligns favorably with the operations definition cycle that necessarily lags the design cycle.

7 SCHEDULE

7.1 EVA ROBOTIC ELEMENT

7.1.1 FTS MANIPULATOR

Costs for a flight experiment of the FTS Manipulator arm cover a four year effort commencing after the start of FY93. The first years effort (FY93) will (a) define revisions required to the MMAG design of the Data Management Processor System (DMPS) to allow remote controlled operations, (b) provide research of program relevant tasks and sponsors, (c) begin the development of individual task panels by each participating Center to address their interest in the flight experiment, and (d) initiate the development of engineering units for the required supporting electronics and mechanisms. The second year's effort (FY94) will develop the flight components previously prototyped. FY95 will complete the flight system development, integration, testing, and qualification to support a late 1995 flight. After completion of the arm in June of 1993, JSC is committed to an environmental testing program for the Flight Manipulator.

7.1.2 AERCAM

The project will be scoped for technical content during the balance of FY92 and the first quarter of FY93. Design and development, based on successful SAFER testing, will occur during FY93 and into FY94. Assembly, fabrication, testing, and integration of the flight unit would occur during FY94 and part of FY95 with qualification testing, to support the late-1995 flight experiment date.

7.2 IVA ROBOTIC ELEMENT

A task survey of potential uses for an IVA robot will be conducted in the last quarter of FY92 through the first quarter of FY93 at JSC. After completing this review and analyzing the results, TRIWG members will be consulted on the inclusion of the IVA robot in the flight experiment design process.

7.3 GROUND CONTROL

Previous development work at JSC in remote ground control stations would be capitalized on and finalized during the first quarter of FY93. It requires the ability to interface with multiple remote controlled systems, such as the FTS manipulator, the AERCAM, and, possibly, the IVA Robot. Development, build, and test of the ground station would occur during FY93, along with a TDRSS linkage test. A flight support system interface development is required, and would occur during FY94, allowing confirmation of the other flight experiment platforms. Qualification of the flight components would occur in early FY95 to support the late-1995 flight experiment.

7.4 FLIGHT EXPERIMENT SCHEDULE OPTIONS

Each of the elements of the proposed flight experiment are at different levels of readiness. For instance, the FTS Manipulator, originally scheduled as a flight experiment, is nearly 100% designed with fabrication to be completed in mid-1993. The AERCAM system benefits from previous work conducted at JSC in the SAFER program while only definition studies have been initiated on the IVA robot. Therefore, it is possible to move the FTS and AERCAM forward in time, to mid-1995, to meet an earlier flight date. The IVA robot could be flown at a later time. This option is attractive if an early flight date or phased program is desired. The reason for proposing the single flight experiment composed of both EVA and IVA components is reduced cost. By targeting a single flight, the overhead of integrating into multiple launch schedules is avoided.

8 SUMMARY

JSC recommends a Space Shuttle based robotics flight experiment that includes robotic flight elements with ground control by astronauts. The proposal offers configurations for an integrated experiment consisting of an EVA fixed base manipulator, an EVA free flyer, and an IVA robot or subset options thereof. The EVA fixed base manipulator utilizes the flight arm currently being completed in the FTS Technology Capture task and could include coinvestigation by other Centers who would provide experiment subobjectives and associated task panels and who would also train the astronauts in the performance of their respective portions of the flight experiment. The free flyer element would provide a television camera, would be fail safe, and could be operated in the payload bay under ground control without danger to the crew or the Orbiter. The IVA robotics experiment requires further definition and initial efforts would be used to clarify the value added of such an experiment. Project estimates indicate that a flight date in late 1995 is viable.